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Structural and compositional shifts in Cerrado fragments in up to 11 years monitoring

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ABSTRACT. The Cerrado has a wide diversity of fauna and flora, and the knowledge of its horizontal structure, in different time intervals allows the prediction of its structural and floristic characteristics. The aim of this study was to evaluate the changes in structure and composition of tree community in three fragments of Cerrado with low anthropization, in an interval of 11 years at Minas Gerais state. Rectangular plots of fixed size were sampled, measuring stem diameter and height of all living arboreal individuals with diameter at 1.30 meters above ground (DBH) ⩾ 5 cm. The tree vegetation dynamics study of the areas was performed, as well as the floristic analysis and the diametric structure. Considering all fragments and years of measurement, the recruitment of trees surpassed its mortality. The basal area varied between 3.67 and 13.07 m².ha⁻¹. The studied areas, considering all fragments and years of measurement, showed a Shannon diversity index (H') from 3.43 to 3.87 nat.ind⁻¹ and Pielou equitability index (J') ranged an interval between 0.77 and 0.82. The similarity calculated by the Jaccard index (J), when performed per plot considering the three fragments, showed a value of 0.2653. Also, related to the development and growth of the study areas, it can be inferred that all fragments and their respective years of measurement had a J-inverse pattern. In conclusion, it can be inferred that the three fragments maintained a representative growth in number of individuals and basal area.

Keywords: tree community dynamics; diversity; ingrowth; recruitment; similarity; vegetation.

Introduction

Natural formations harbor a wide diversity of fauna and flora, playing important ecological and hydrological functions that support human communities in their surroundings (Almeida et al., 2012; Tambosi, Vidal, Ferraz, & Metzger, 2015; The Brazil Flora Group [BFG], 2015). Therefore, natural resources are of great environmental, as well as social and economic importance, providing indispensable ecosystem services to humanity and the environment (Gamfeldt et al., 2013).

The Cerrado stands out among the plant formations of great relevance in the world, as being the second largest Brazilian vegetation domain – behind only the Amazon Forest – with an extension of approximately 2 million km² (Silva Neto, Oliveira, Ferreira, Souza, & Viola, 2016; Silva, Azevedo, & Silveira, 2011). In addition, the Cerrado domain is ranked as one of the world's hotspots for conservation, due to the biodiversity it harbors, high endemism rate and constant threats suffered (Strassburg et al., 2017). It is noteworthy that the Cerrado vegetation presents a high number of animal and plant species (Carvalho, Bernacci, & Coelho, 2013; Carvalho, Marco Júnior, & Ferreira, 2009; Ganem, Drummond, & Franco, 2013).

Due to the intense anthropic activities undertaken, without proper precaution, that is, with an intense exploitation of natural resources, the Cerrado is currently among the most threatened vegetation in the world (Strassburg et al., 2017). Several agricultural and forestry activities are developed within the domain, leading to ecosystems degradation and, consequently, the suppression of endemic species, increasing endangered species and the worsening of climatic changes (Ahrends et al., 2010; Carmo, Vasconcelos, & Araújo, 2011). Activities such as these resulted in a loss of 423,798 hectares of the Cerrado native vegetation (16,549,138 Mg of plant biomass) from 2007 to 2017 in Minas Gerais state, Brazil (Silveira, Terra, Acerbi-Júnior, & Scolforo, 2019). When analyzing the entire area of Cerrado in Brazil, agricultural activities take up

about 39% of the areas that used to be natural vegetation. For these reasons, the domain has turned into a large agricultural frontier of the country (Sano, Rosa, Brito, & Ferreira, 2010).

Considering the scenario exposed, the knowledge regarding the horizontal structure in of tree communities, in different time intervals, allows a deeper understanding about their performance over time (Meyer et al., 2015) and about the ability of providing ecosystem services (Cordeiro, Pereira, Terra, & Mello, 2018). Thus, the evaluation of ecological processes occurring in the vegetation, as well as the fluctuations in composition and structure are relevant to the knowledge of functioning of these ecosystems. One way to evaluate such fluctuations in time is through the study of tree community dynamics (Meyer et al., 2015).

Specifically, the study of tree vegetation dynamics allows to infer about community interactions related to maintenance of richness, as well as characterization of existing diversity (Fontes & Walter, 2011; Oliveira et al., 2018). These analyses provide information on recruitment, mortality, and growth of a vegetation, which makes possible to predict the floristic and structural changes over time (Silva Neto et al., 2017). Moreover, with these data is possible to understand the relationship of cause and effect caused by changes in the community, as well as to support the decision-making related to ecosystem restoration, conservation and use of forest management (Magurran et al., 2010).

Considering the target vegetation, the Cerrado domain, studies about dynamics of local tree communities are relatively common in the literature (e.g. Almeida et al., 2014; Silva Neto et al., 2016; Gomes et al., 2016). Generally, studies related to vegetal community dynamic correspond to an interval between three and seven years because of the low growth from the natural formations (Franczak et al., 2011; Mews, Marimon, Maracahipes, Franczak, & Marimon-Junior, 2011; Miguel, Marimon, Oliveira, Maracahipes, & Marimon-Junior, 2011; Silva Neto et al., 2017).

However, studies that contemplate successive measurements that could potentially better describe the functioning of tree communities are scarce, mainly due to the difficulties involved in monitoring permanent plots (Kuuluvainen & Aakala, 2011). Besides that, it is common to have studies which are focused in the dynamics' analysis in just one place (Almeida et al., 2014; Silva Neto et al., 2016). In this study, the focus is centered in two different phytophysiognomy, which are shrub savanna and cerrado *stricto sensu*. In this sense, the dynamics analysis provides information concerning the functioning of the ecosystem, as well as a better understanding of the vegetation behavior which validates the importance they have in providing subsidies on the strategies to preserve and restore the vegetation (Silva Neto et al., 2017). In addition, this analysis indicates the ability of these ecosystems to provide services as carbon stock (Cordeiro, Pereira, Pinto, Terra, & Mello, 2019).

In this context, the aim is to describe and understand structural and floristic fluctuations in up to 11 years monitoring of the tree community in three Cerrado fragments in Minas Gerais state. Due to the areas characterization and low anthropization index, it is expected all fragments to have a recruitment rate greater than mortality as well as gain rate in basal area higher than loss.

Material and methods

Study areas and data collection

The data of this study come from three native fragments, located along the São Francisco River Basin and the Jequitinhonha Valley in Minas Gerais, and its characteristics are described in Table 1 (Scolforo, Mello, & Oliveira, 2008).

It is important to emphasize that due to its low number of individuals, in the periods evaluated, the fragment I was described as Shrub Savanna. The fragment II was characterized by an advanced stage of regeneration, that is, during the time of the inventory measurement it showed very few characteristics of anthropic activities, as well as there is a great number of individuals with total height greater than four meters. Regarding the fragment III, this one showed little evidence of anthropization, that is, a little indication of intervention (Scolforo et al., 2008).

In addition, fragment III is characterized by the presence of watercourses with perennial and intermittent stream as well as a swampy plain (known as vereda in Brazil) inside of it (Figure 1). It is noteworthy that the plots in the fragment III were sampled outside the vereda searching to characterize the vegetation in the surroundings. Thereby, all study areas are characterized by low anthropic impact being free of selective cuts. However, since it is an extensive area, there is an occasional cattle flow. In addition, all fragments are legally protected by the Law 12651/12 (Brasil, 2012), and are considered as permanent preservation areas or legal reserves. The surrounding vegetation from all fragments are similar, with a great

index of forest plantation and presence of watercourse. The fragments are inserted in private properties belonging to reforestation companies in Minas Gerais.

Table 1. Characterization of Cerrado fragments situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively.

| Description	Fragment I	Fragment II	Fragment III
Area (ha)	236.85	111.9	178.11
Phytophysiognomy	Shrub savanna	Cerrado *sensu stricto*	Cerrado *sensu stricto*
Municipality	Brasilândia de Minas	Olhos d'Água	Corinto
Longitude	45º51'30.12"W	43º47'55.40"W	44º21'10.21"W
Latitude	16º56'33.84"S	17º20'39.23"S	18º 27'55.63"S
Annual precipitation (mm)	1285.92	1187.21	1312.12
Mean annual temperature ℃	22.95	20.91	21.48
Altitude (m)	578	855	643
Soil	Latosol	Latosol	Cambisol
Plots (First inventory)	40 (4 hectares)	11 (1.1 hectares)	11 (1.1 hectares)
Plots (Second inventory)	40 (4 hectares)	24 (2.4 hectares)	20 (2 hectares)
Plots (Third inventory)	40 (4 hectares)	24 (2.4 hectares)	20 (2 hectares)
Sample size		10 x100 (1000 m²)	
Figure	1A	1B	1C
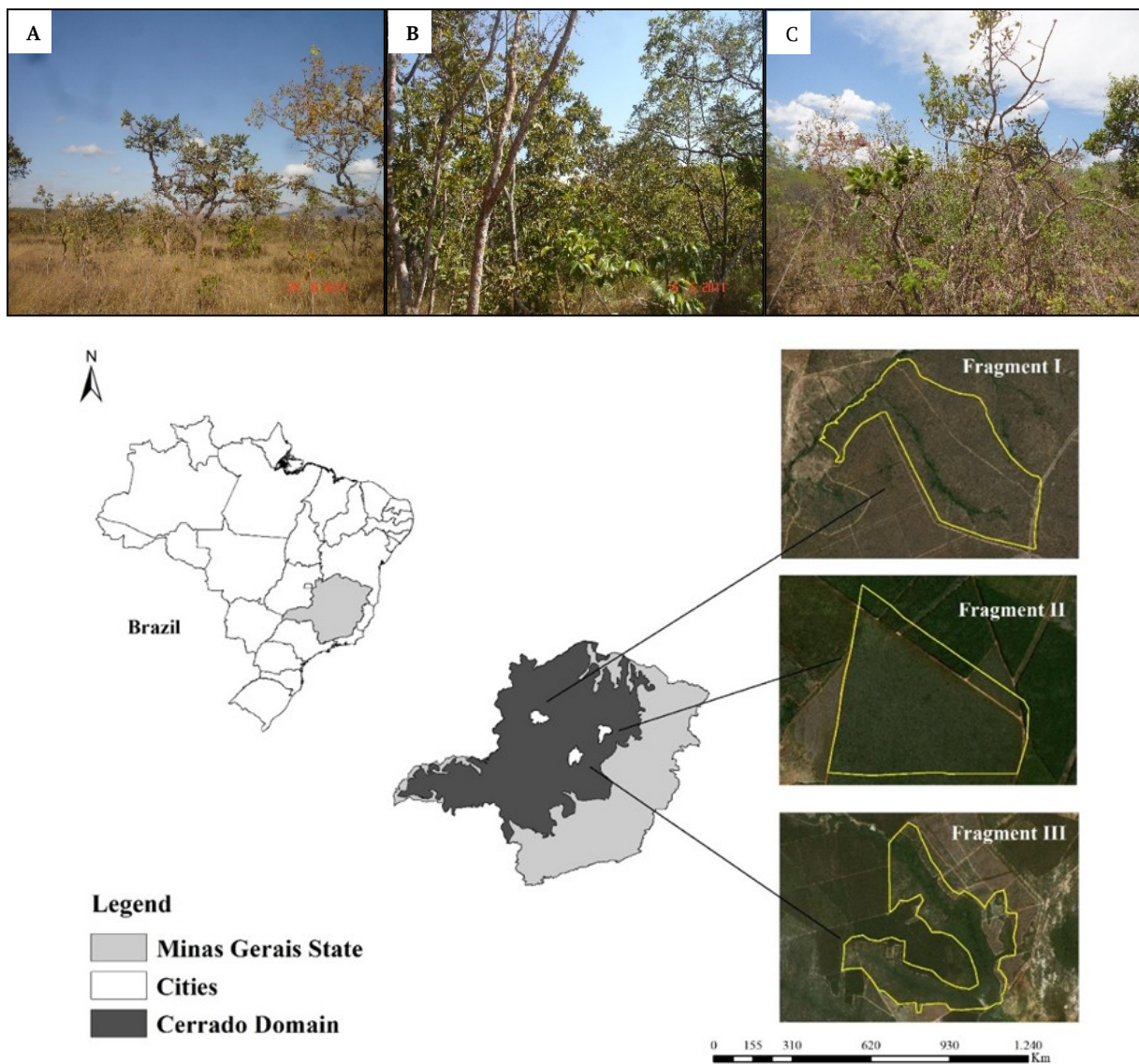
Figure 1. Study areas located in Minas Gerais state, Brazil. A) Fragment I with characteristic vegetation of shrub savanna located in the municipality of Brasilândia de Minas; B) Fragment II with vegetation of cerrado *sensu stricto* located in the municipality of Corinto; C) Fragment III with vegetation of cerrado *sensu stricto* situated in the municipality of Olhos d'Água.

The sample design used on the forest inventory, in all fragments was from the systematic sampling (Silva Neto et al., 2017) (Table 1). The forest surveys were carried out in three periods for each fragment (fragment I: 2003, 2010 and 2014, fragment II: 2003, 2005 and 2010, fragment III: 2002, 2005 and 2013).

In each plot, all living arboreal individuals with diameter at 1.30 meters above ground (DBH) $\geqslant 5$ cm were measured. Total height of these arboreal individuals was registered using a telescopic measurement stick with five centimeters of accuracy (Batista et al., 2016; Silva Neto et al., 2017; Scolforo et al., 2008). Thus, the quantification of dead and recruited trees was performed, considering as recruit all arboreal individuals that reached the minimum diameter for inclusion in each inventoried period. In addition, considering the analysis processing, all the individuals that showed tillering had the diameter transformation to one value.

It was collected botanical material and produced exsiccates to proceed the botanical identification by specialists. Following, the exsiccates were deposited in the *Universidade Federal de Lavras* herbarium (ESAL) (Scolforo et al., 2008), and the species were classified according to the APG IV (The Angiosperm Phylogeny Group [APG], 2016). Also, the plots were georeferenced, and all measured trees were labeled with a metal tree tag describing the plant and plot number. The metal tag was fixed at the height of 1.30 meters from soil, in order to guarantee the measurement of arboreal individual at the same height in the future measurements.

Data Analysis

Tree community dynamics study

The arboreal community changes were evaluated over the years for each fragment. Therefore, it was calculated the mean annual rates of mortality (M), recruitment (R), loss (L) and gain (G) in basal area, as well as turnover rates in number of trees (mortality and recruitment) and basal area (loss and gain). The models used to determine mortality, recruitment, loss and gain in basal area were proposed by Sheil and May (1996); Sheil, Jennings, and Savillt (2000). Regarding to turnover in number of individuals and basal area, the models used were proposed by Oliveira-Filho, Mello, and Scolforo (1997). Finally, net change rates for number of individuals (ChN) and basal area (ChAB) were determined as described by Korning and Balslev (1994).

The analyzes of the plant community dynamics were processed by using the "forest.din" function (Higuchip, 2018) in R software (R Core Team, 2017). All sampled plots were used for the evaluation of tree dynamics. However, there is a difference in the number of sample plots between the periods evaluated for fragments II and III. For those fragments, in the first analysis interval 11 plots were considered and for the second period a total of 24 plots and 20 plots were considered, respectively. It is noteworthy that all dynamics rates, in number of individuals and basal area, were provided in hectare. In this way, even with the different number of plots in each fragment, the results are in the same scale.

The dynamics rates from all fragments and intervals were tested for normality using Kolmogorov-Smirnov test, with a significance level of 95%. Considering that the data showed a normal distribution, in order to perform a comparison using paired t-test, dynamics rates were recalculated separately considering the initial plots at all intervals within each evaluated fragment. Therefore, for fragment II and III, the 11 plots measured since first inventory were considered. The paired t-test aims to verify the existence of a significant difference between means of the variables of interest (Ribeiro, Sanchez, Pedroni, & Peixoto, 2012; Zar, 2010). For this study it was analyzed statistical difference in the rates of mortality, recruitment, loss, gain, net changes and turnover in number of individuals and basal area for each fragment.

Floristic Analysis

The species diversity for each fragment and year of measurement was calculated by Shannon-Wiener index (H') which considers the logarithmic transformation of species density. The characterization of community uniformity was calculated by Pielou equitability index (J') (Magurran, 2011). Also, in order to provide a better visualization from the results, it was proceeded a rarefaction analysis considering the last year of measurement of each fragment, using the *Vegan* package in R software (Oksanen et al., 2019).

The floristic similarity analysis between areas was proceeded in four steps: between plots of all the fragments, between fragment I and II, fragment I and III, fragment II and III. For that, from the data of last year of measurement of each fragment, the absolute density matrix transformed into presence and absence was used. The density matrix addressed only those individuals classified at species level, that is, all

individuals not identified or classified only at genus level were disregarded for this analysis. The evaluation was based on Jaccard similarity coefficient (J), which varies between 0 and 1 (Brower, Zar, & Von Ende, 1997) and according to Felfili et al. (2011) when the coefficient exhibits a value greater than 0.5 it is considered that the communities have a high similarity between them. The processing to floristic similarity was from *Vegan* package (Oksanen et al., 2019) through the programming software R (R Core Team, 2017).

Diametric structure

In order to evaluate the distribution by diameter class of arboreal individuals over time in the inventoried fragments, the analysis of diametric structure was carried out. For that, frequency histograms of individuals number were elaborated using the center of diameter class. It was considered an amplitude of 5 cm for all fragments and years of measurement (Silva Neto et al., 2017; Silva & Souza, 2016). The histograms were generated from MS - Excel program (Microsoft).

In order to verify the existence of statistical difference between observed frequencies of arboreal individuals for the inventoried intervals in each fragment, a non-parametric test, the Wilcoxon-paired test was performed by using the Action Stat tool in Excel. This test is commonly used to analyze related samples (Andreazzi, Pires, Pimenta, & Fernandez, 2012).

Results and discussion

Through all inventories, it was quantified to the fragment I a number of 40 families, 75 genus and 99 species. The most representative families in number of individuals was Fabaceae, followed by Myrtaceae, Malpighiaceae and Vochysiaceae. For fragment II were identified 34 families, 65 genus and 89 species. The families with highest number of individuals were Fabaceae, Sapotaceae, Myrtaceae and Malvaceae. Finally, to fragment III were found 38 families, 88 genus and 120 species. The order of most representative families in number of individuals were Vochysiaceae, Fabaceae, Myrtaceae and Annonaceae. Considering the florist composition, the fragment III even with the smaller sampled area, it showed the highest richness. This result can be explained by the presence of a vereda into the area which provides a greater humid to the place. Beyond that, the fragment has a greater precipitation and the soil is classified as Cambisol which is more fertile and has smaller percentage of aluminum than Latosol (Neri et al., 2012).

The most expressive families in the evaluated fragments corroborate with what is expected for the Cerrado tree communities (Giácomo, Carvalho, Pereira, Souza, & Gaui, 2013; Mews et al., 2011; Rios, Sousa-Silva, & Malaquias, 2018). Generally, the Fabaceae family is found among the most representative in terms of richness and abundance which is followed by the Vochysiaceae family (Almeida et al., 2014; Nettesheim et al., 2010; Terra et al., 2017). Thus, the cosmopolitan characteristic of Fabaceae family is evidenced, that is, because of the large number of genus and species, it can be found in several formations (Flores & Rodrigues, 2010).

The results showed an increase in number of species when comparing inventoried intervals at the same fragment. This result may be related to sampling intensity which was altered in the second year of measurement in the fragments II and III. The fragment I was the only one that suffered loss of species in second interval, from 96 to 95. In the 2005-2013 interval, fragment III showed a tendency of stabilization at the number of species. This result is explained by the theory of species accumulation curve, which represents the tendency of species increase as sampled area increases (Giácomo et al., 2013; Schilling, Batista, & Couto, 2012). The results found in this study were superior to species level when compared with other studies for the same phytophysiognomies (Almeida et al., 2014; Moura, Gomes-Klein, Felfili, & Ferreira, 2010; Pinto, Lenza, & Pinto, 2009) (Table 2).

It should be noted that when considering all fragments and its inventoried intervals, there were an increase in number of individuals represented by an interval from 410 to 1617 individuals per hectare. In addition, even if fragment III is equally classified with the fragment II as cerrado *stricto sensu*, that one showed greater increase in number of arboreal individuals per hectare.

The vegetation dynamics showed that the number of recruits was higher than number of dead trees in all periods and areas measured. This result points out to the self-regeneration behavior of the vegetation (Bernasol & Lima-Ribeiro, 2010; Mews et al., 2011; Carvalho, Fagg, & Felfili, 2010). Accordingly, the recruitment rate stood out in relation to mortality rate in all areas, in the respective time intervals. It was noted that fragment II had only six dead trees per hectare, even considering the short period of

measurements between 2003 and 2005. In addition, when compared to the other areas and considering the number of individuals per hectare, fragment III had a major increment, resulting in a net gain of 227 arboreal individuals, being this a result of the mortality of 102 trees and recruitment of 329 trees.

Table 2. Parameters of tree community dynamics to fragments of Cerrado situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively. Where: n is number of plots sampled; N: number of individuals; BA: basal area; Ch. N: net change rate in number of individuals; TURN. N: turnover in number of individuals; TX: rate; Ch.BA: net change rate in basal area; TURN. BA: rotation in basal area.

	Fragment					
	Fragment I		Fragment II		Fragment III	
Phytophysiognomy	Shrub savana		Cerrado *sensu stricto*		Cerrado *sensu stricto*	
Interval	2003-2010	2010-2014	2003-2005	2005-2010	2002-2005	2005-2013
n	40	40	11	24	11	20
	Rate per number of individuals					
$N.ha^{-1}$ (Fist year)	410	564	1425	1446	1059	1249
$N.ha^{-1}$ (Second year)	564	652	1540	1617	1245	1476
Species (First year)	89	96	72	85	79	125
Species (Second year)	96	95	76	90	89	125
Survivors trees ha^{-1}	382	526	1419	1413	1035	1147
Dead trees ha^{-1}	29	37	6	34	24	102
Recruited trees ha^{-1}	182	125	121	206	210	329
Net Gain in trees	153	88	115	172	186	227
Mortality (% $year^{-1}$)	1.02	1.7	0.22	0.47	0.75	1.05
Recruitment rate (% $year^{-1}$)	5.42	5.2	4.01	2.67	5.97	3.1
Ch. N (% $year^{-1}$)	4.65	3.69	3.94	2.26	5.55	2.11
TURN. N (% $year^{-1}$)	3.22	3.45	2.11	1.57	3.36	2.08
	Rate per basal área					
BA ($m^2.ha^{-1}$) - First year	3.67	4.93	9.61	10.37	7.96	10.77
BA ($m^2.ha^{-1}$) - Second year	4.93	5.71	10.86	12.33	10.67	13.07
Dead trees ($m^2.ha^{-1}$)	0.1613	0.2384	0.0206	0.1745	0.0954	0.7236
Recruited trees ($m^2.ha^{-1}$)	0.5271	0.3375	0.3008	0.597	1.7244	1.1047
Decrement BA ($m^2.ha^{-1}$)	-0.0391	-0.0549	-0.0477	-0.101	-0.3297	-0.3515
Increment BA ($m^2.ha^{-1}$)	0.9276	0.7355	1.0188	1.6307	1.4061	2.2712
Loss rate (% $year^{-1}$)	0.8	1.52	0.36	0.54	1.81	1.31
Gain rate (% $year^{-1}$)	4.88	5.08	6.27	3.91	10.93	3.67
Ch. BA (% $year^{-1}$)	4.29	3.74	6.31	3.51	10.24	2.45
TURN. BA (% $year^{-1}$)	2.84	3.3	3.31	2.22	6.37	2.49

Due to the Cerrado idiosyncrasies, a low mortality rate is more propitious to occur over time when compared to other vegetation formations (Ribeiro et al., 2012). This fact can be attributed to the existing relation with edaphoclimatic characteristics, thus establishing that the vegetation elaborates adaptation strategies for maintenance of individuals as fire protection mechanisms, water stress, low soil fertility and regrowth capacity (Silvério & Lenza, 2010; Lopes & Miola, 2010; Fidelis & Pivello, 2011). For instance, Mews et al. (2011) found an annual average mortality of 4.01% $year^{-1}$ and a 6.67% $year^{-1}$ recruitment in one cerrado *sensu stricto* area. For the present study, considering all fragments and measurement intervals, the mortality rate ranged from 0.22 to 1.7% $year^{-1}$ and recruitment rate from 2.67 to 5.97% $year^{-1}$. Despite the adverse environmental conditions and possible area conservation status these results provide vegetation survival exactly how is expected for the phytophysiognomy under study.

The basal area evidenced a progressive increase for all inventoried periods in each fragment varying between 3.67 and 13.07 $m^2.ha^{-1}$. The fragment III, when compared to the others, showed an increase of basal area, considering the period between 2002 and 2013. This result may be related to the fact that this area presents little human intervention, as well as greater water availability, due to the presence of a vereda and water courses within the fragment. The fragment I, which has predominant shrub savanna vegetation, did not exhibit great variations at basal area because this phytophysiognomy is characterized by presenting individuals sparse among themselves. The obtained basal area values are within the expected interval for the Cerrado formations (5.5 - 18.85 $m^2.ha^{-1}$), as verified in several studies (Almeida et al., 2014; Moura et al., 2010; Rios et al., 2018). The evaluation of gain and loss rates allows to predict, in relation of basal area, an increase for all fragments and intervals analyzed, since the results showed a superiority of gain in relation to

loss. Also, the net change rate in basal area was positive in all analyzes, being a result of recruitment higher than mortality. The gain in basal area represents greater carbon stocking, which is an important ecosystem service linked to vegetal formation performance as a carbon sink (Bello et al., 2015; Lopes & Miola, 2010).

Through the analysis of tree community dynamics, for shrub savanna and cerrado *sensu stricto* areas at their respective evaluated intervals, the results provide insights that allow to infer about status of fragments conservation. All study areas exhibited a development regarding increase of biomass and number of individuals per hectare. Since the fragments did not present great damages to vegetal formation structure, these results are probably because they resisted to possible anthropic actions, like fire and presence of cattle in the areas.

The paired t test performed, considering a same number of sample units for all intervals within the fragment, showed that mortality as well as net change and turnover in basal area presented a statistical difference in all areas evaluated. In other words, considering the two intervals of dynamics in each fragment the three rates showed differences, that is, different behavior between the periods of analysis. It is important to highlight that net change in basal area was positive, thus confirming the significance of recruitment and growth of vegetal formation. Therefore, it should be noted that there was an increase in the basal area due to the increase in number of individuals (Table 3).

Table 3. Paired t test to community dynamics rates in three Cerrado fragments situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively. Where: N: number of individuals; BA: basal area; M: Mortality; R: Recruitment; Ch. N: Net change in number of individuals; TURN. N: Turnover rate in number of individuals; L: Loss or decrement; G: Gain or increment; Ch. BA: Net change in basal area; TURN. BA: Turnover rate in basal area.

Parameters	P-value - Fragments			
	Rates	Fragment I	Fragment II	Fragment III
N	M	8.32E-04*	1.01E-02*	4.76E-02*
	R	1.49E-01	1.17E-02*	1.24E-01
	Ch. N	5.28E-03*	5.19E-03*	8.89E-02
	TURN. N	2.18E-01	3.15E-02*	1.75E-01
BA	L	9.06E-04*	9.11E-02	4.85E-01
	G	2.89E-01	9.58E-06*	1.53E-02*
	Ch. BA	1.42E-02*	3.04E-05*	2.97E-02*
	TURN. BA	4.87E-03*	1.72E-05*	1.30E-02*

*: Significant at 5%.

The floristic diversity varied between 3.43 and 3.87 nats.ind^{-1} and it was estimated by Shannon-Wiener index (H') for all fragments and respective years of measurement. The Pielou equability presented a range of 0.77 to 0.82. These values allow to infer the heterogeneity of the vegetation, that is, regarding the distribution of the individuals among the species (Table 4).

Table 4. Shannon diversity and Pielou equability parameters of Cerrado fragments and their respective years of measurement evaluated which are situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively. Where: H' is the diversity of Shannon; J' is the Pielou equitability index.

	Fragments								
	I			II			III		
Year	2003	2010	2014	2003	2005	2010	2002	2005	2013
H' (nats.ind^{-1})	3.70	3.70	3.67	3.50	3.47	3.49	3.43	3.84	3.87
J'	0.82	0.81	0.81	0.82	0.78	0.77	0.78	0.79	0.80

The diversity values found in this study corroborate with the range presented in other studies of cerrado *sensu stricto* (Aquino, Pereira, Passos, & Oliveira, 2014; Moura et al., 2010; Nettesheim et al., 2010; Silva & Souza, 2016; Silva Neto et al., 2016). The study area characterized by shrub savanna vegetation (fragment I) presented a diversity of 3.70 nats.ind^{-1} in the first two years of measurement and of 3.67 nats.ind^{-1} in the last year and these results are higher than values of other studies in the same phytophysiognomy (Corsini, Scolforo, Oliveira, Mello, & Machado, 2014). Thus, it can be inferred that these results are characteristic of the vegetation under study indicating a high diversity (Aquino et al., 2014). The floristic results can be better visualized from the rarefaction graphic which provides the difference in richness among the three

fragments. Also, it confirms that the three areas have a different diversity and the fragment III represents the higher richness (Figure 2).
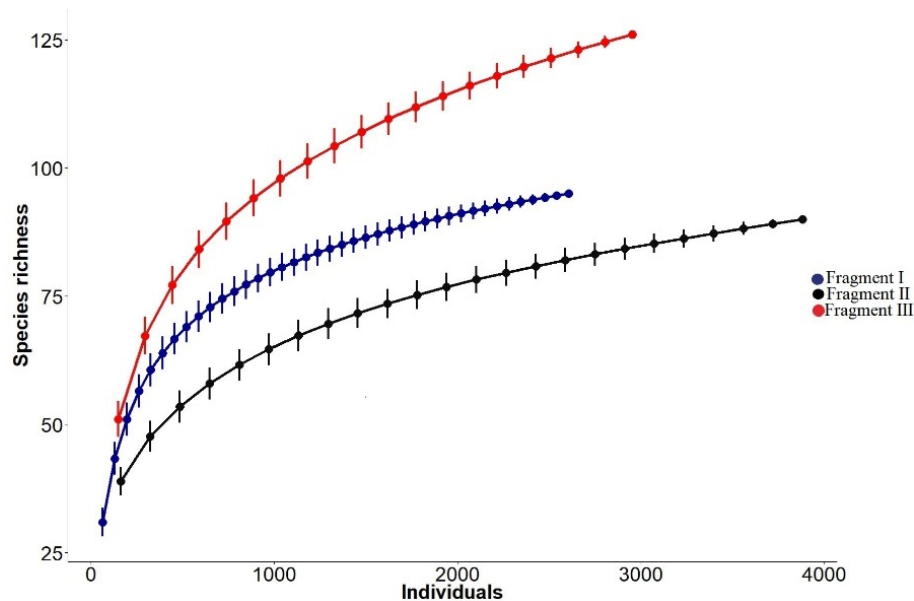

Figure 2. Rarefaction analysis from the last year of measurement into each area studied into Cerrado fragments situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively.

The similarity for all plots and fragments was 0.2653 (Figure 3). However, when comparing fragments, it was observed that fragment II and III showed a greater similarity between them (0.3260). On the other hand, the evaluation between fragment I and II was 0.2979 and between I and III was 0.2824. These results were expected because fragment I differs from the others fragments regarding predominant shrub savanna vegetation. Despite the results, it should be noted that some of the species which are present into the fragment I are like the species from the plots in the fragment II. In general, through Jaccard's similarity values it can be inferred that there is a low similarity between the areas because all of them were lower than 0.5. Prado-Júnior, Lopes, Vale, Dias Neto, and Schiavini (2012), performing floristic, structural and ecological comparison of vegetation of the phytophysiognomies of an urban remnant of Cerrado, also found low values of similarity which varied from 0.034 to 0.329. Couto, Anjos, Toledo, Pereira, and Queiros (2009), evaluating areas of Cerrado under different levels of anthropization, reported about their low similarity indexes, ranging from 0.08 to 0.23.
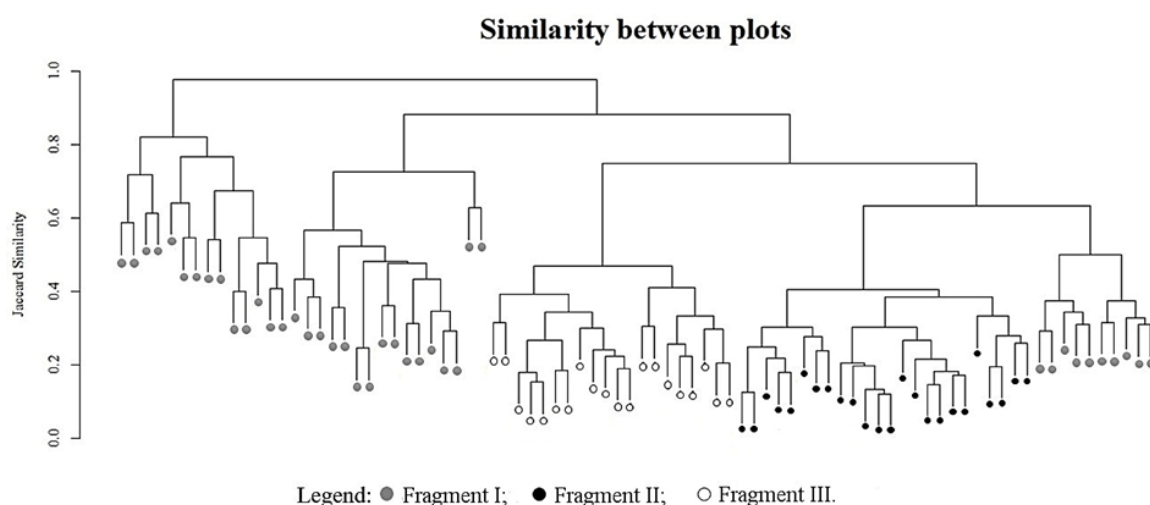

Figure 3. Jaccard similarity index dendrogram of Cerrado fragments situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively.

Regarding to diametric distribution, the fragments and their respective years of measurement presented the J-inverted or negative exponential pattern, which is expected to natural formations (Silva Neto et al., 2016). These results imply in a greater number of individuals concentrated in the first diameter classes, as well as it allows to infer the balance between mortality and recruitment, once a high concentration of trees in the first classes indicates the introduction of new individuals (Silva & Souza, 2016).

Thus, the first class of diameter, in each inventoried period, presented an average of approximately 64% of individuals for fragment I, 67% for fragment II and 62% for fragment III (Figure 4). Nonetheless, the structure of Cerrado phytophysiognomy can be influenced by factors such as conservation and fire. In this study a fire event did not occur, and it provided the recruitment and consequently the maintenance of individuals in the first class to all fragments. The presence of fire events makes the first class of individuals more susceptible to mortality. For instance, Almeida et al. (2014) reported changes in density of individuals as a result of four fire events that occurred in an area of cerrado *sensu stricto* evaluated during a period of 27 years.
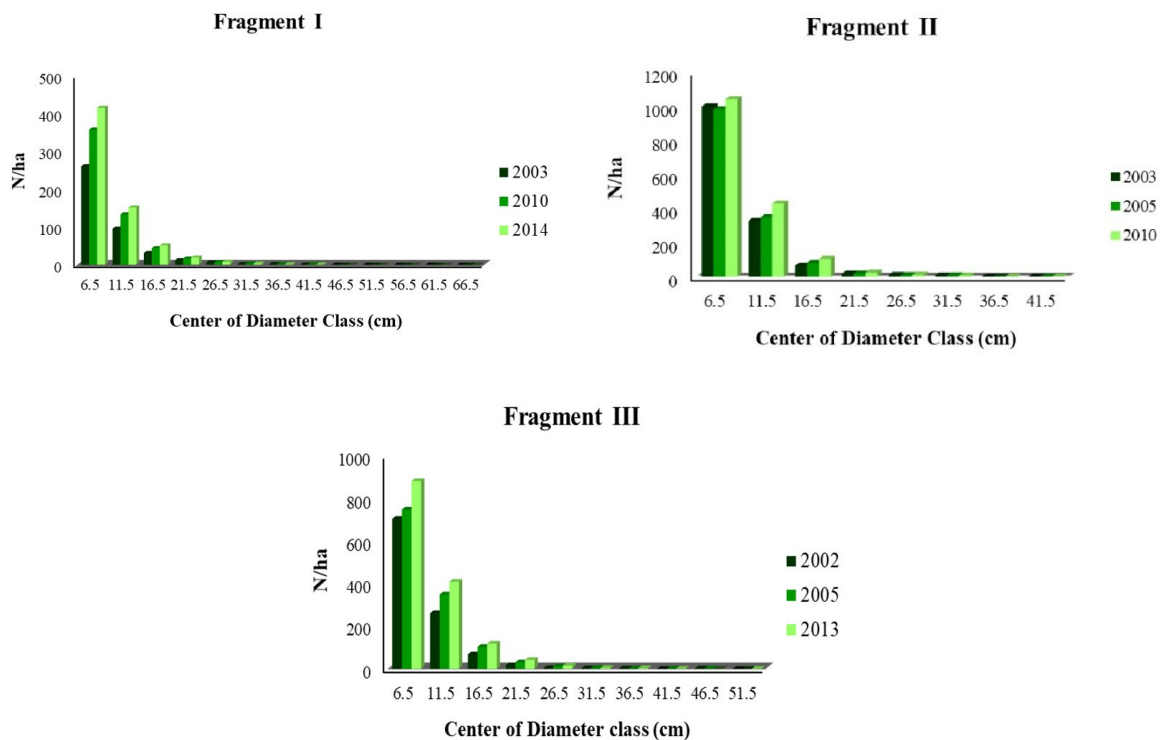

Figure 4. Frequency distribution of diameters classes to all individuals measured in each fragment and their respective intervals per hectare in Cerrado areas situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively. Where: N is the number of individuals.

According to Wilcoxon-paired test it is possible to verify the existence of a statistically significant difference between the frequencies observed in each interval for all fragments (Table 5). This result confirms the growth of vegetation in the analyzed periods as verified by the tree community dynamics.

Table 5. Wilcoxon-paired test between the frequencies observed in each diameter class, considering the diametric distribution of each sampled period, to Cerrado fragments which are situated in Minas Gerais state, Brazil, which are: Fragment I with phytophysiognomy of Shrub Savanna located in Brasilândia de Minas; Fragment II and III with phytophysiognomy of cerrado *sensu stricto* located in Olhos d'Água and Corinto, respectively.

Fragment	Interval	p-value
I	2003-2010	0.0279*
	2010-2014	0.0223*
II	2003-2005	0.0141*
	2005-2010	0.0346*
III	2002-2005	0.0091*
	2005-2013	0,0208*
*: Significant for p <0.05		

Conclusion

The fragments maintained a representative growth in number of individuals and basal area as well as their floristic richness and species composition were stable throughout intervals. It was possible to inference regarding low similarity between the areas, even though when they were classified as belonging to the same phytophysiognomy, thus emphasizing the great beta-diversity of Cerrado. It is worth emphasizing the conservation importance of these fragments for the Cerrado domain maintenance, since the increase in basal area and recruitment in both individuals and species indicates that vegetal formation has the power to act as carbon sink, among other ecosystem services.

Acknowledgements

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